Exploratory Analysis – Using All the Tools in Our Kitbag

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Robert S. Alexander

robert.s.alexander@saic.com

Michael E. Garrity

michael.e.garrity-2@saic.com

NOTE: The views expressed in this presentation are those of the authors, and do not represent the FFW program, the Department of Defense, or the U.S. Government.

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- A classic error in Operations Analysis is to use the tool we are most familiar with to solve every problem that comes our way…
- The better way is to assess each problem and design a methodology to solve the problem with whatever tools are most suitable.
- Exploratory Analysis* is a methodology designed to solve a certain class of problems, using a whole range of tools:
  - Human-in-the-loop wargaming
  - Simulation
  - Regression Analysis
  - Costing
  - Spreadsheet and Database Analyses
  - Mathematical Programming

*not to be confused with a similarly-named analysis approach developed by RAND Corporation. This approach is based on analysis methods developed at USACAA for Value Added Analysis.

Example Analytical Study

- Future Force Warrior* – Exploratory Analysis
  - Capital budgeting / cost effectiveness analysis
  - Considers about 15 possible proposed Soldier and platoon capabilities (e.g., enhanced Night Vision, Blue Soldier Tracking, Platoon UAV, etc.)
  - Combat model runs generate platoon effectiveness measures for various combinations of capabilities
  - Regression analysis estimates marginal effectiveness of each capability and pair of capabilities.
  - Final analysis is done with an integer program that maximizes force effectiveness subject to cost, weight, and power constraints.

*FFW was an Army ATD run by Natick Soldier RDEC from 2002 through 2007 that investigated various individual Soldier technologies in a platoon context.

Future Force Warrior Program Goals

- There were many candidate capabilities and technologies to investigate for the Infantry Small Combat Unit

- The Program had a dual nature:
  - The ***engineering*** and ***experimentation teams'*** goals were to build and demonstrate actual systems
    - » Does it work?
    - » How mature are the technologies?
    - » Does it contribute to combat effectiveness as expected?
  - The ***analysis team*** also had the goal to determine what capabilities are actually important and cost-effective
    - » So what?
    - » Does a given capability contribute to combat effectiveness
    - » What are the most cost-effective contributors to combat effectiveness

Focus: Technologies

Focus: Capabilities

Future Force Warrior's "Exploratory Analysis" process

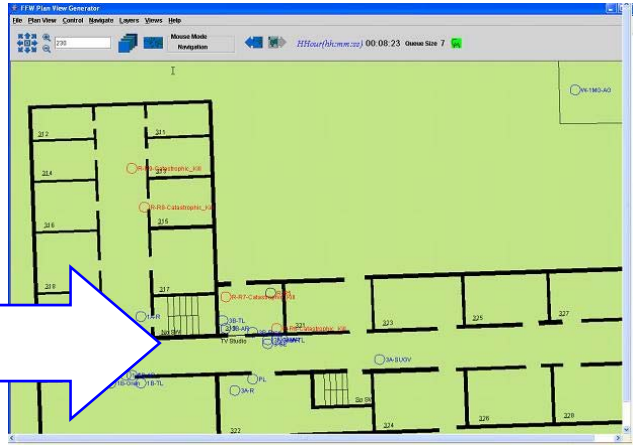
MAPEX Activities

"Brief, Wargame, Discuss, Survey"

- Wargame selected tactical tasks in the context of the MOUT vignette

Tactical Subject Matter Experts are "role-playing" "**Gamers**"

Gamers' version of the operation is used to guide simulation scripting



Simulation: Estimates Contributions to Combat Effectiveness

- Design a run matrix that prescribes runs using various combinations of the capabilities under consideration
- Run multiple replications of each “case”
- Do regression analysis on the results
- A capability’s regression coefficient represents its marginal contribution to overall combat effectiveness

Run Matrix Example

System / Run	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	1
NVG		1	1	1	1	1	1	1	1								
HUD			1		1		1		1		1		1		1		1
Body Armor		1		1	1		1	1	1			1	1			1	
Blue Soldier Tkg		1		1		1	1		1	1	1			1	1		1
Cooperative Eng			1	1	1		1		1		1		1		1	1	1
Plt UAVs			1	1		1	1		1	1			1	1		1	
Squad SUGVs		1		1		1		1		1		1		1		1	
Digital Radio			1		1	1		1	1	1			1	1			
Thermal Scope			1		1		1	1		1	1	1			1	1	
Soldier Sensor		1			1	1		1		1		1		1		1	1
Haptic Alerts			1	1	1		1		1		1		1		1	1	1
IFF			1	1		1	1		1	1			1	1		1	
[illegible]		1		1										1		1		1

Regression: Combat Effectiveness Estimation Methodology

- EXPERIMENTAL DESIGN: Vary the mix of capabilities in each run; experimental design specifies which capabilities to represent in each run.

Specifies X_{ik} (presence of capability i in run k)

- SIMULATION: measures force effectiveness for each replication.

Computes Y_k (realization of MOE for run k)

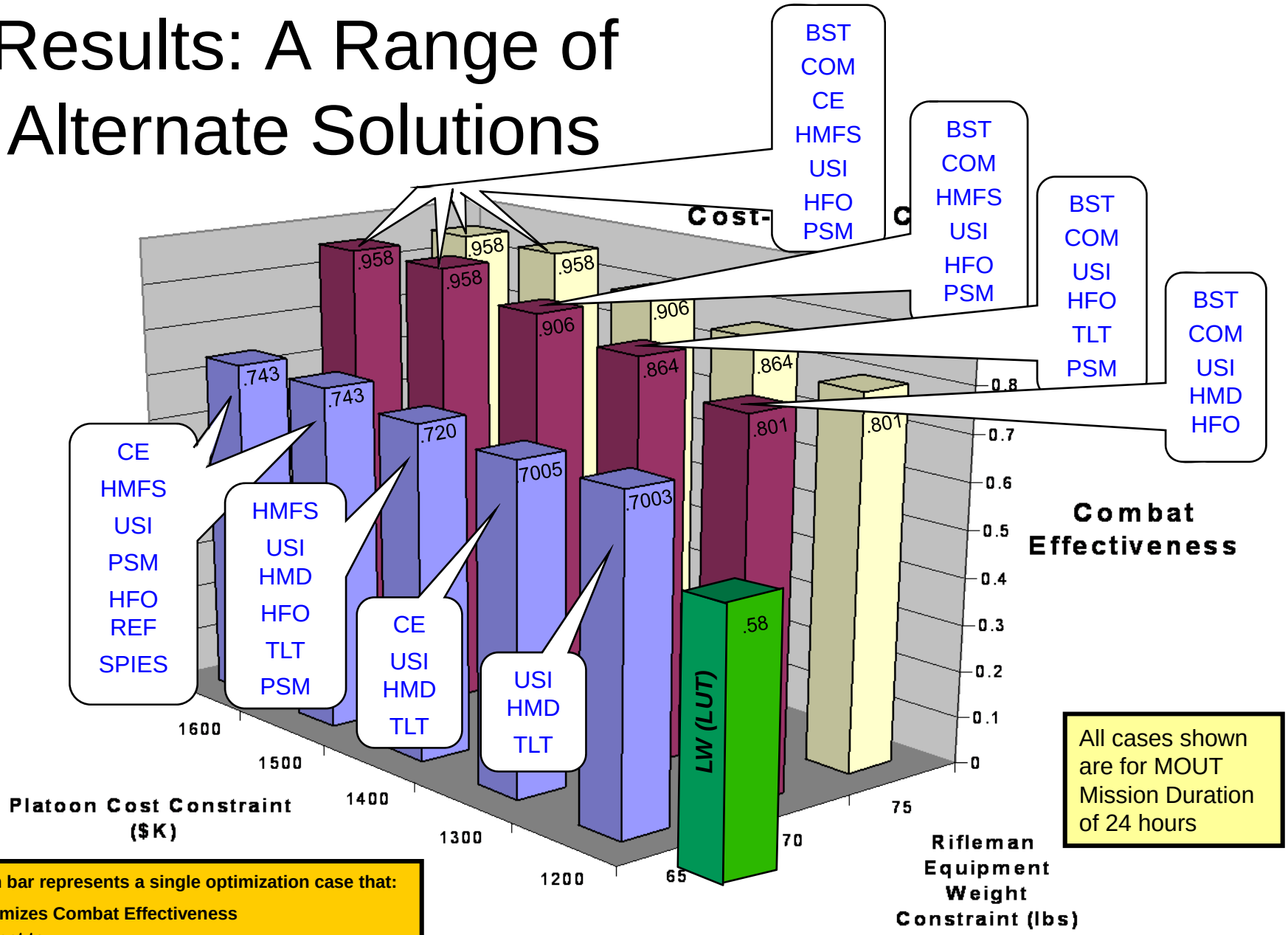
- SYSTEM EFFECTIVENESS ESTIMATION: Fit a hyperplane to the results of the combat model; "Slopes" of the surface estimate each capability's marginal contribution to force effectiveness.

Solves for β_i (contribution of capability i) and β_{ij} (contribution of pair of capabilities i and j) such that $\Sigma_k (\varepsilon_k^2)$ (or $\Sigma_k |\varepsilon_k|$) is minimized in $Y_k = \beta_0 + \Sigma_k \beta_i X_{jk} + \Sigma k \beta_{ik} X_{ik} X_{jk} + \varepsilon_k$

Mathematical Program: Cost-Benefit Analysis

- Maximize combat effectiveness
- Subject to:
  - Life-cycle cost
  - Soldier load
  - Power consumption
  - Duration of mission

Results: A Range of Alternate Solutions



All cases shown are for MOUT Mission Duration of 24 hours

Each bar represents a single optimization case that:

Maximizes Combat Effectiveness

Subject to:

- **Platoon Procurement Cost Limits**
- **Rifleman Load Limits**
- **Mission Duration Requirements**

NOTE: Results are illustrative only; actual analysis results were not for public release.

Summary

- Exploratory Analysis was used by the Future Force Warrior program to assess cost-effective technologies for the dismounted Infantry Platoon.
- EA used a variety of tools to solve the particular problem being addressed.